

The Online Data Quality Monitoring System at BESIII^{*}

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Abstract The online Data Quality Monitoring (DQM) plays an important role in the data taking process of HEP experiments. BESIII DQM samples data from online data flow, reconstructs them with offline reconstruction software, and automatically analyzes the reconstructed data with user-defined algorithms. The DQM software is a scalable distributed system. The monitored results are gathered and displayed in various formats, which provides the shifter with current run information that can be used to find problems early. This paper gives an overview of DQM system at BESIII.

Key words BESIII, DQM, Sampling, histogram

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1 Introduction

BESIII is a detector operating on Beijing electron-positron collider (BEPCII) at the Institute of High Energy Physics (IHEP) of the Chinese Academy of Sciences in Beijing. With design luminosity of $10^{33} \text{cm}^{-2} \text{s}^{-1}$ of BEPCII, BESIII will collect large data samples so that τ -charm physics can be studied with high precision^[1].

The peak luminosity has exceeded $6 \times 10^{32} \text{cm}^{-2} \text{s}^{-1}$ recently. At so high luminosity, it's essential to monitor the status of the BESIII hardware and to determine the quality of acquired data in time. In the online environment, the DAQ (Data AcQuisition) system uses all the acquired data to get preliminary information of sub-detectors. But because of the multi-beam bunches and the pipelined readout electronics system, some information such as event start time cannot be obtained in the DAQ system. Offline reconstruction can give much more information about the detector performance and data quality, but its results will not be available until several days after data is taken. To monitor data quality both in an accurate way and in real time, the online Data Quality Monitoring system (DQM) is developed. DQM fully reconstructs part of the acquired data, which is

sampled randomly from online data flow, using the offline full reconstruction software. The monitored results on detector status and data quality will be available only a few minutes after one run begins.

2 Properties and operating environment

The BESIII online DQM system consists of 8 nodes: 5 IBM eServerBlade HS20, each with dual 3.0 GHz Xeon CPUs, and 3 PCs. All nodes have SLC 4.6 operating system installed. 5 HS20 nodes process the event data, including event reconstruction and analysis. one PC is used as DQM system server to provide system management and DQM services, such as histogram merge and histogram display; one PC deals with Event Display; the other one is the backup machine.

The communication between DQM and DAQ is only handled by high speed network connection. Events copied from the online data stream are transferred one by one to DQM machines through the network and does not influence the online data flow. Only a part of the events in data are sampled. The sampling rate depends on the processing capacity of the DQM programs. Most of the time consuming

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process is the data reconstruction. As for now, the maximum sampling rate can reach 360 Hz. And the ratio of signal events (Bhabha, Dimuon and Hadron events) is about 40~60 Hz.

The BESIII DQM software framework was developed based on the framework of the ATLAS DQMF^[2] and BESIII offline software system (BOSS). The work flow is redesigned to ensure the separation from the DAQ software system and automatic control under BESIII environment. Only a data server is required to run in the online DAQ system. The data server samples data from the online data flow and then sends the data to DQM processes by TCP connections. The design ensures the safety of the DAQ system. And DQM system integrates with BOSS tightly. Almost all the offline algorithms can run under the DQM environment with minor or no modification. DQM system is a distributed system. There are totally 20 DQM main processes running on the HS20 nodes. The histograms generated by each main process are merged by Histogram Merger process in real time. Then the merged histograms can be checked during the data taking and are stored in root files after a run finished. The detector properties such as TOF time resolution, MDC momentum resolution obtained from each run are stored in the DQM database for stability check of the detector.

3 The architecture of DQM

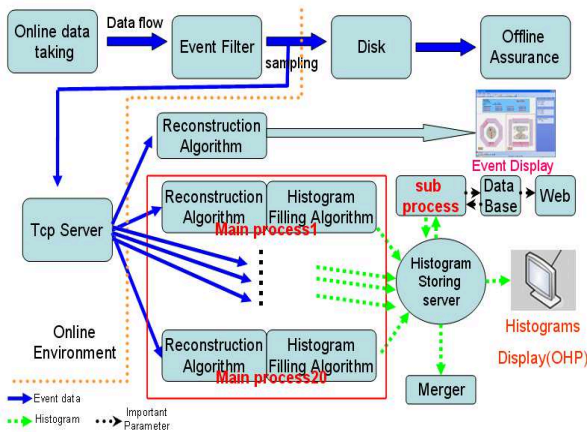


Fig. 1. The framework of DQM (color online)

The framework of DQM[3] is shown in Fig. 1. DQM system consists of 6 main parts, i.e. DQM Server, DQM clients, Merger, Histogram Storing server, DQM database and information display programs. DQM Server is used to get data from online data flow. DQM clients invoke reconstruction algorithms and data analysis algorithms to reconstruct events and fill

histograms. Merger is used to merge histograms from different DQM clients. Histograms Storing server is where all histograms are stored. DQM database stores parameters that reflect detector properties and data quality of each run. Information display programs are used to display information that is useful for monitoring data quality.

3.1 Basic work flow of DQM

The event fragments received from different sub-detectors are assembled into full events and filtered (Event Filter^[4]). A TCP server, which is called DQM Server, is used to sample (copy) events passed the Event Filter and then deliver them to different DQM clients.

DQM clients reconstruct events to get basic information of each sub-detector. A small part of the reconstructed events are displayed directly by Event Display program, while the other are used to fill first-class histograms (histograms filled with information in event level). The first-class histograms from different DQM main processes are merged by a Histogram Merger after they are published to Histogram Storing server. Some of the merged histograms will be displayed by Online Histogram Presentation program (OHP) directly and some will be used to generate second-class histograms (histograms filled with information extracted from first-class histograms) to be displayed by OHP. Some global parameters of sub-detectors, such as momentum resolution, time resolution, event vertex and so on, are extracted from the histograms in the end of the run and stored into DQM database.

3.2 DQM Clients/DQM main processes

There are 22 DQM clients currently, including main process, sub-process and event display. 20 DQM clients are DQM main processes which fully reconstruct the events and then fill first-class histograms using the information in the reconstructed events. DQM sub-process used to handle first-class histograms in the end of a run. Event display program fully reconstructs the events and displays it visually in real time, as shown in Fig. 2.

Framework of DQM main processes is shown in Fig. 3. A DQM main process can be divided into 5 functional units. The TCP client is used to fetch events from DQM Server. Then the interface program unpacks the data and supplies events in the format suitable for reconstruction algorithms. DQM uses the offline reconstruction algorithms to fully reconstruct the events. Histogram-filling algorithms (user defined

algorithms) use the information of the reconstructed events to fill histograms. Histogram publish program publishes histograms to Histogram Storing server.

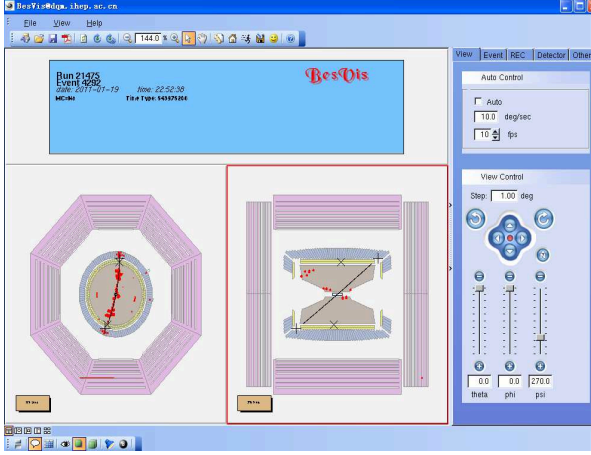


Fig. 2. A Bhabha event displayed by Event Display (color online)

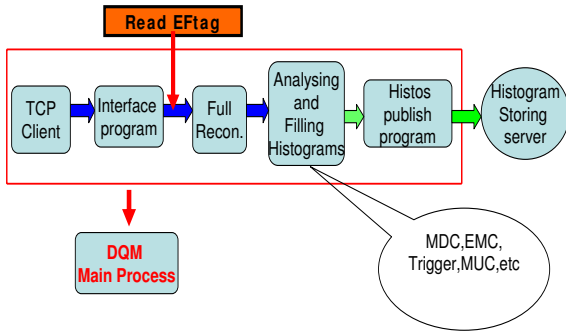


Fig. 3. Framework of DQM main processes (color online)

To improve the processing ability, the KalFitAlg algorithm^[5] used for track fitting is not used in DQM online reconstruction, which is different from offline reconstruction. As a result, the time spent on event reconstruction decreases almost 50% while the precision of DQM result is slightly worse than offline result. Another important difference between DQM reconstruction and offline reconstruction is that DQM reconstruction uses the calibration constants from recent runs.

In order to further improve the process capacity of DQM system, event tags given by Event Filter are checked by a specific algorithm, which is executed before the event reconstruction and only events with specific Event Filter tag are reconstructed. The processing rate of DQM improved 44% under current configuration.

3.3 Histogram-filling algorithms (user defined algorithms)

DQM main processes invoke user-defined histogram-filling algorithms to fill histograms. The algorithms are flexible and independent of each other. Each of the histogram-filling algorithms can be added or removed easily, which ensures the extensibility of DQM system.

Many histogram-filling algorithms have been developed to fulfill the task of monitoring. A special event tag algorithm is used for event classification using the reconstructed information. Each event processed by DQM is tagged as Bhabha, Dimuon, Hadron, Cosmic Ray and so on for later use.

Main histogram-filling algorithms are used to monitor the sub-system of BESIII, including MDC(Main Drift Chamber), TOF(Time-of-Flight counters), EMC(Electro-Magnetic Calorimeter), MUC(Muon Counter), and trigger system. All these algorithms can use the event tags from event tag algorithm to fill histograms with some kind of events only. Furthermore, several histogram-filling algorithms related to some special physics channels, such as inclusive K_S , inclusive J/ψ in ψ' data, D meson in ψ'' data, and so on, are developed, which give a more physics to monitor the data.

Each of the detector-related algorithms has a sub-algorithm to fill second-class histograms using the first-class histograms it filled. DQM sub-process invokes sub-algorithms to extract information in the merged first-class histograms and get parameters such as detecting efficiency, noise ratio, energy resolution, etc. and then fills second-class histograms with these parameters. Some important parameters are stored into DQM database which is a subset of BESIII Offline Database^[6]. These parameters are fetched back to draw the historical curve in order to monitor the run stability.

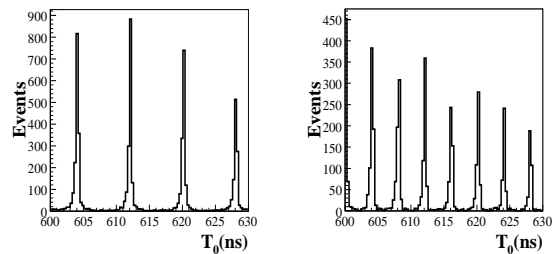


Fig. 4. Event start time

Integral luminosity, event start time, event vertex, etc are also monitored in the DQM system,

which are sensitive to the beam condition. The accelerator monitoring system can get them from DIM[7](Distributed Information Management System) either. Fig. 4 is an example of event start time with different beam intervals (8ns left, 4ns right). The shift can found the change of the beam interval quickly during data taking.

4 Cooperation of DQM processes

DQM system is a completely automatic system in the data taking. The flow control system, based on TCP connections, controls different components of the DQM system to ensure all of them taks right action at right time.

When taking data during a Run, DQM Server will send events to DQM main processes by TCP connections automatically. Once receiving events, DQM main processes will reconstruct them and generate first-class histograms.

At the end of a run, DQM main processes will publish all histograms of this Run into Histogram Storing Server and then send a TCP signal to Merger. After receiving the TCP signals from all 20 DQM main processes, Merger will merge the histograms in Histogram Storing Server, and then send a TCP signal to DQM sub-process. After that, DQM sub-process will fetch the first-class histogram from Histogram Storing Server, generate second-class histogram, publish second-class histogram to Histogram Storing Server and then send a TCP signal to DQM Histogram Storing Server. At last DQM Histogram Storing Server will store all histograms of the Run into a ROOT file after receiving the TCP signal from DQM sub-process.

All TCP connections are protected by time-out mechanism. The DQM processes with TCP connections will wait for TCP signals before taking further step. But if the TCP signals can not be received after a fixed time, they will take action without the TCP signals so that when some DQM processes are broken, the other processes can work still.

Several daemon processes are running to recover DQM system from unexpected errors. Once a DQM process crashes, it will be restarted automatically.

5 Information display

DQM results are viewed in three ways: Event Display, Histogram Display, and Web Display.

The Event Display program is modified according to the offline version in BOSS. The reconstructed

events can be displayed automatically in real time. Fig. 2 shows a Bhabha event displayed by Event Display program. Two tracks can be seen clearly.

Histograms from different user-defined algorithms can be viewed easily using tools OHP or OHD. Important histograms of each sub-detectors and typical physics processes are displayed on OHP. All the physical variables filled into these histograms are shown in table 1.

separated parts	histograms (most given X axis only, Y is number of Bhabha events by default)
MDC	Momentum of e^+ and e^- , Residual ^[9] distribution, event start time, dE/dx , ϕ and $\cos\theta$ of e^+ and e^- , drift time in inner/outer chamber
TOF	ΔT of Barrel/Endcap, East Barrel/West Barrel/Endcap hit map, barrel z of the hit position, time resolution of Endcap, time difference between upper and lower TOF
EMC	Shower energy deposited in Barrel/Endcap EMC, Shower ϕ in Barrel/Endcap, Shower ID(θ)
MUC	ϕ vs. $\cos\theta$ for all events, fired layers in MUC of tracks, event No. vs. number of MUC hits, acollinear angle distribution of the momentum of dimu tracks
Trigger	Fired ADC number for Barrel/Endcap, scintillator ID for Barrel/Endcap, long track hit map, trigger channel, trigger condition
Physics	ϕ of e^+ and e^- for Barrel, $\cos\theta$ of e^+ and e^-

Table 1. Histograms displayed on OHP to be checked by shift personnel.

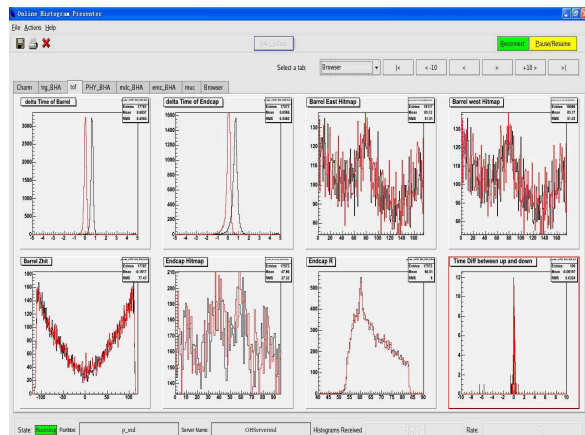


Fig. 5. An example of displaying histograms by OHP (color online)

Most of the histograms shown on OHP are displayed with reference histograms, as shown in Fig. 5. The reference histograms come from a recent good run. The shifter can find problem easily from OHP when it occur. For example, first two histograms in Fig. 5 do not agree with their references. Careful check points out that it is caused by the accelerator problem.

OHD is a tool which can be used to check all the histograms of current run by experts on sub detectors and other people who are authorized. ROOT can also be used to check the historical histograms stored into ROOT files.

Important parameters of detectors in each Run stored in DQM database can be checked in tables or by histograms on the web. People can check the momentum resolution and space resolution of MDC, time resolution of TOF, energy resolution of EMC, peak value of shower energy deposited in EMC for e^+ and e^- and the mean value of x,y,z of the event vertex. The integral luminosity of each run are calcu-

lated with Bhabha events and Di-photon events separately, and can also be checked on the web.

6 Summary

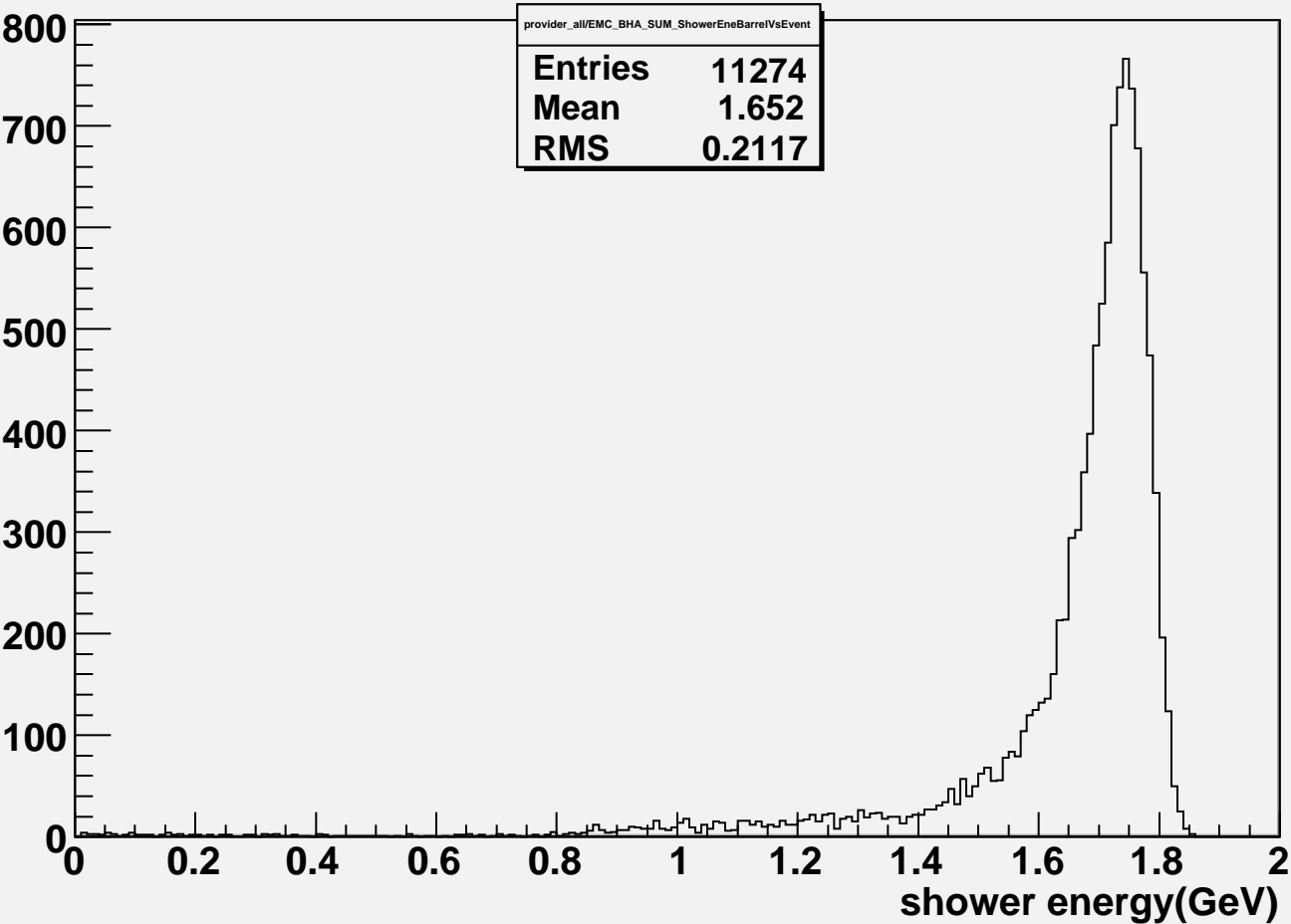
DQM system has been developed and implemented in BESIII. After tuning and updating carefully for the first several months, DQM has been running continuously and steadily during BESIII data taking process for more than two years since July, 2008. DQM system can monitor the sub-detector and trigger system in much more physical and accurate way than the other online monitoring system. DQM has become an essential part of the whole BESIII data quality monitoring system. Together with the online DAQ monitoring system, DQM ensures the successful and robust data taking and physics analysis on BESIII.

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Data flow



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Offl

